

Scintillator and fibers

Van Nguyen

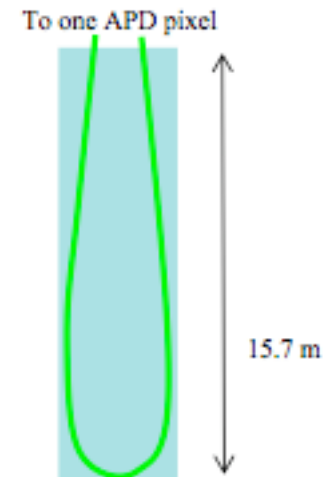
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Outline

- Liquid scintillator
 - NOvA
 - FINeSSE
- Triangular extruded scintillator
 - MINERvA
 - D0
- Fiber prices
- Electronics
- Simple G4Beamline simulation

Liquid scintillator (LS)

- NOvA uses WLSF in LS (3.9cm wide, 6cm deep PVC cells)
- Expert on NOvA (Carl Bromberg) says that they have tested Kuraray Y-11 S-type (0.6–0.8mmD) WLSF in LS (50% & 10% pseudocumene at 40C) for ~1 year “without evidence of failure”
 - **Warnings:** *Must not expose end of the fiber to LS – it will dissolve the polystyrene core. Any crack (e.g. from excessive bending) in the cladding that allows scintillator to get to the core will cause the fiber to die*



NOvA

Fig. 6.3: A single liquid scintillator filled PVC cell with a 0.8 mm diameter looped WLS fiber shown in green.

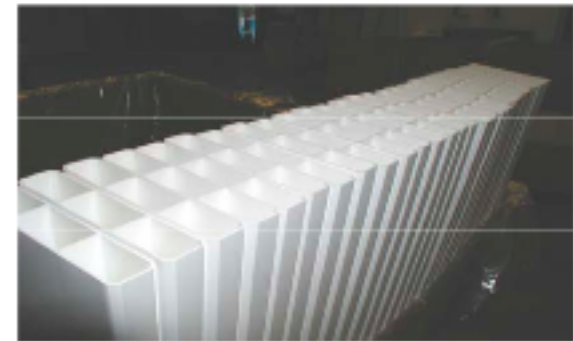


Fig. 6.6: Cell structure of the three cell prototype of extruded PVC with 12% TiO₂.

Liquid scintillator (LS) cont'd

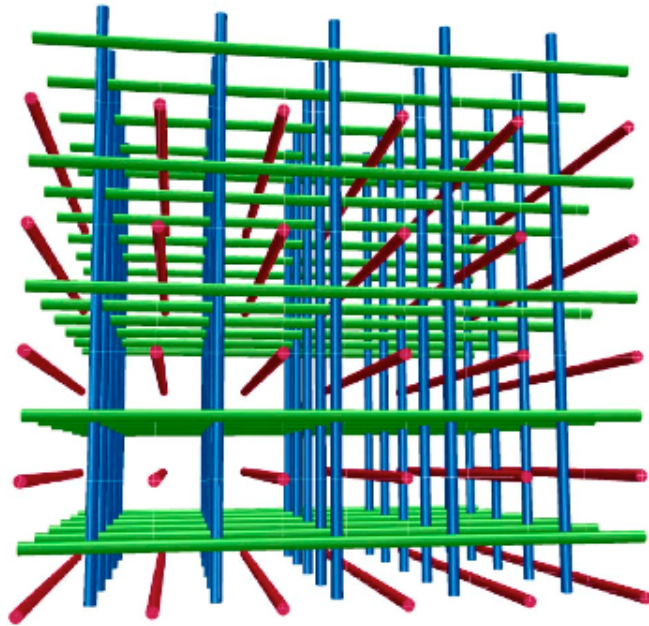


Fig. 1. Geometrical arrangement of wavelength-shifting fibers inside the tank.

FINeSSE

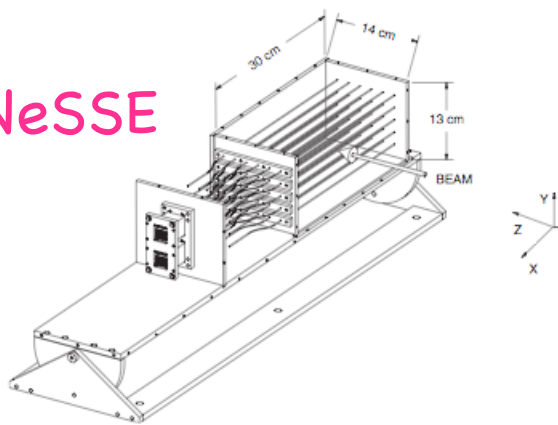


Fig. 2. Assembly drawing of the prototype detector. There are 5 rows of 6 fibers for a total of 30 wavelength-shifting fibers. The beam is incident along the z-axis.

- WLSF can be used in LS if one chooses the LS correctly. R. Tayloe et. al have built and tested such a detector
 - "A large-volume detector capable of charged-particle tracking." Nucl. Instr. Meth. A 562: 198-206, 2006
 - Light-tight container filled with a mineral-oil based LS
 - WLSF are submersed in the oil, collect scintillation light and guide it to the PMs
- Stacked scintillator disadvantages: tracking resolution is determined by the bar dimension and by the precision with which the bars are manufactured & assembled
- R. Tayloe's opinion is that "in the medical field, one would avoid LS for safety/ease-of-use reasons"
- Bought WLSF from St. Gobain (in US) since more convenient than Kuraray for small amounts

Triangular extruded scintillator: MINERvA

- MINERvA inner detector: 1.7cm height, 3.3cm base, 3.8m long with 2.6mm hole for WLSF
- <http://minerva-docdb.fnal.gov/cgi-bin/ShowDocument?docid=700>
- Kuraray fibers: Y-11, 1.2mmD
 - Fibers glued with optical epoxy
- Light output: determined required # of pe per layer, per mip is 13.2 pe at normal incidence for full readout
- Position resolution requirements:
 - Transverse: 3mm; longitudinal: 1cm

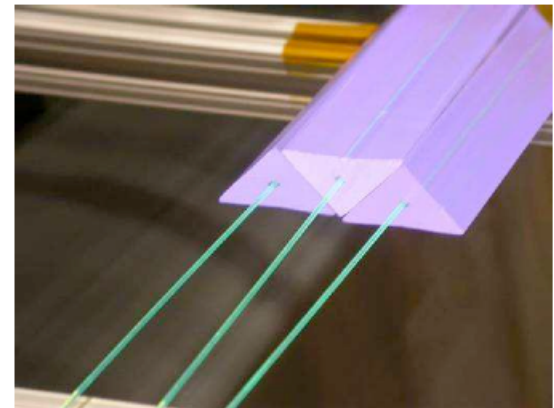


Figure 6: Prototype MINERvA scintillator bars, with wavelength-shifting fibers inserted.

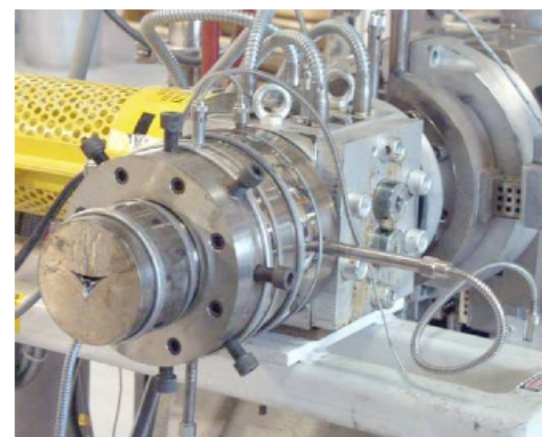
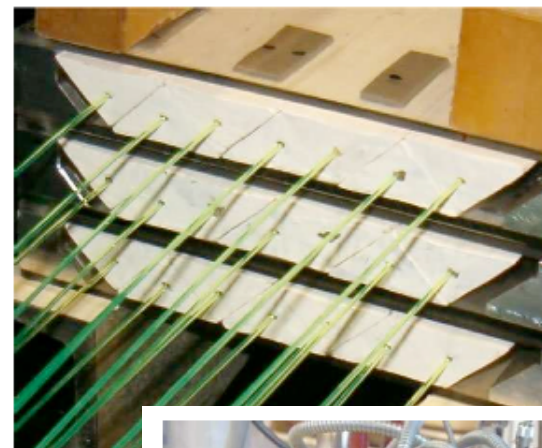
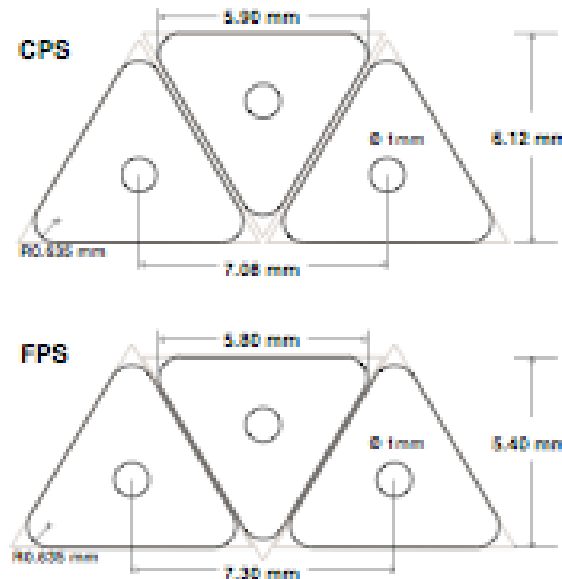


Figure 7: Die to produce MINERvA's triangular strips for ID scintillator.

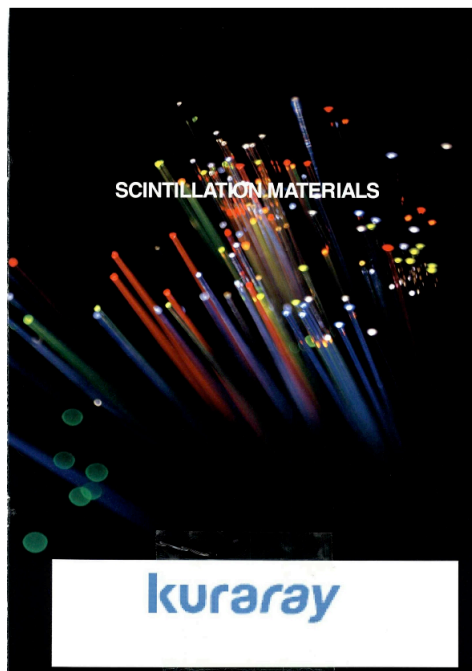
Triangular extruded scintillator: D0

- Central and Forward Preshower (CPS and FPS) detectors
- Fiber: Kuraray Y-11 (0.835mmD)
- Did not glue the fiber in the hole
- Spatial resolution: $\sim 0.6\text{mm}$
- D0 scintillator expert: Abid Patwa (abid@fnal.gov)



Fiber prices: Kuraray

- Fiber diameters produced: 0.5mm to 2.0mm (Yuki Shiomi, Kuraray Co., Ltd.)



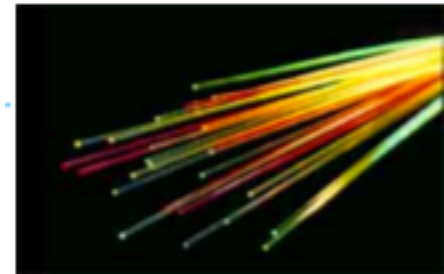
Product Description	Quantity (m)	U Price	Total
WLS Fibers			
Y-11(200)M, 1.0mmD., 500m BJ	500	\$5.57	\$2,785.00
Y-11(200), 1.0mmD., 500m BJ	500	\$4.13	\$2,065.00
Y-9(100)M, 1.mmD., 500m BJ	500	\$3.72	\$1,860.00
Y-9(100), 1.mmD., 500m BJ	500	\$2.75	\$1,375.00
			\$8,085.00

Note: 500m is the min. quantity; Y-8 and Y-9 are the same price

Fiber prices: St. Gobain

<http://www.detectors.saint-gobain.com/>

FiberType	Emission Color	Emission Peak, nm	Decay Time, ns	1/e Length m*	# of Photons per MeV**	%of Emission Spectrum Transmitted by a Wratten #3 Filter***	Characteristics/Applications
BCF-10	Blue	432	2.7	2.2	~8000	40	General purpose; optimized for diameters >250 μ m
BCF-12	Blue	435	3.2	2.7	~8000	44	Improved transmission for use in long lengths
BCF-20	Green	492	2.7	>3.5	~8000	95	Fast green scintillator
BCF-60	Green	530	7	>3.5	~7100	99	3HF formulation for radiation hardness
BCF-91A	Green	494	12	>3.5	n/a	>98	Shifts blue to green
BCF-92	Green	492	2.7	>3.5	n/a	>98	Fast blue to green shifter
BCF-98	n/a	n/a	n/a	n/a	n/a	n/a	Clear waveguide



Sample quote: BCF-91A, 0.5mmD x 100 meters @ \$300. The price does vary by fiber type, diameter, and quantity.

How much fiber?

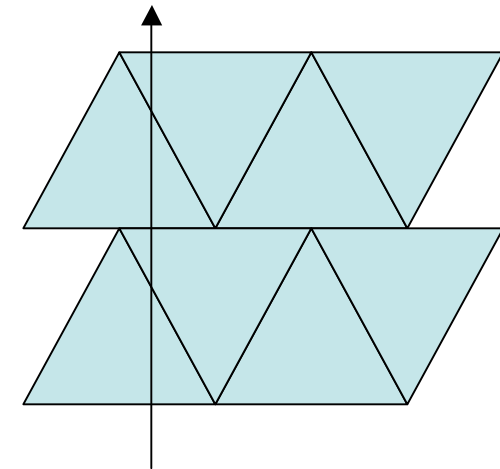
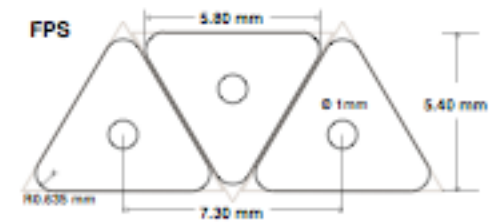
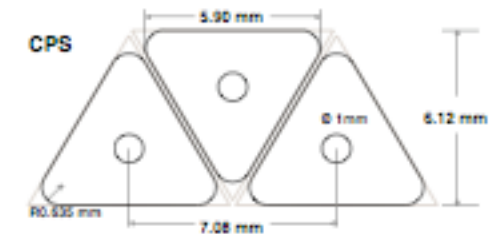
- Would like a detector 10cm x 10cm, i.e. 100mm x 100mm
- CPS die: $100\text{mm}/6.12\text{mm} = 16.34 \rightarrow 17$

rows

- Consider 1 row: $100\text{mm} - 7.08\text{mm} = 92.92\text{mm}$
 - $92.92\text{mm}/(3.54\text{mm}/\text{bar}) = 26.2$ bars
 - Total # bars for 1 row = $1 + 26.2 = \sim 28$ bars
- Total # bars = $17 \times 28 = 476$ bars
- Need $\sim (20\text{cm of fiber}/\text{bar}) \times 476 \text{ bars} = 9520\text{cm} = 95.2\text{m}$

- FPS die: $100\text{mm}/5.40\text{mm} = 18.52 \rightarrow 19$
- rows

- Consider 1 row: $100\text{mm} - 7.30\text{mm} = 92.7\text{mm}$
 - $92.7\text{mm}/(3.65\text{mm}/\text{bar}) = 25.4$ bars
 - Total # bars for 1 row = $1 + 25.4 = \sim 26$ bars
- Total # bars = $19 \times 26 = 494$ bars
- Need $\sim (20\text{cm of fiber}/\text{bar}) \times 494 \text{ bars} = 9880\text{cm} = 98.8\text{m}$



Electronics

Would like to use Nevis electronics (Leslie Camilleri) already developed for Double Chooz Outer Veto detector

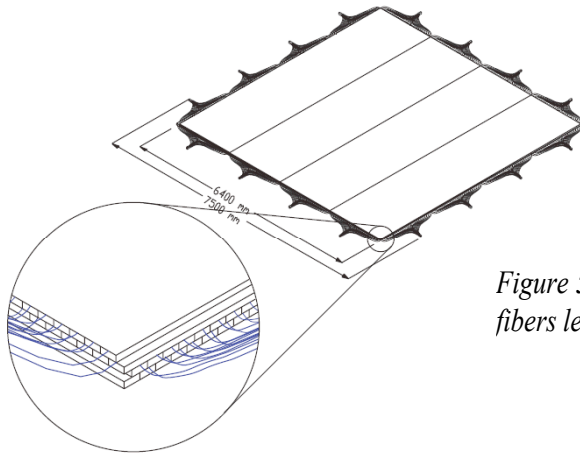
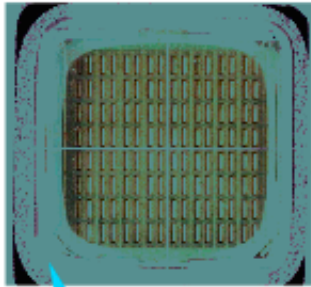
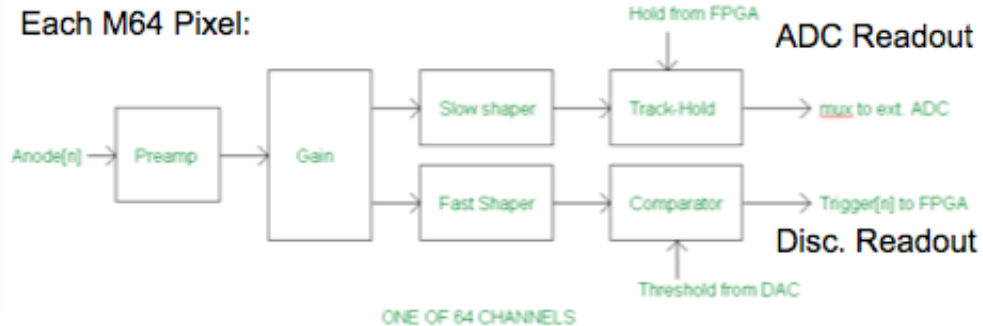
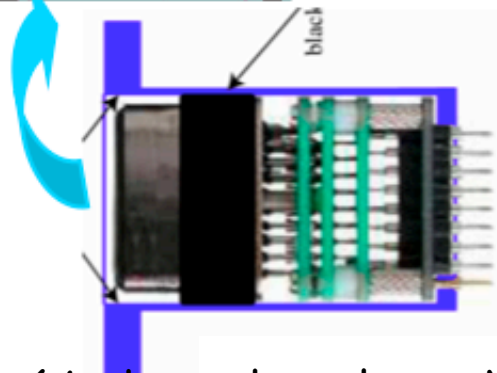


Figure 5: A complete 6.4 m square plane made up of 8 two-layer modules. The inset shows fibers leaving the 4 layers of strips.

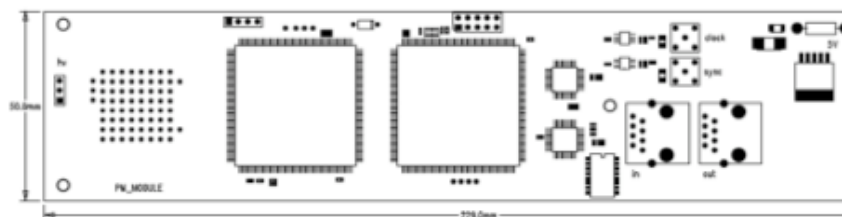
- 5cm x 1cm strips of scintillator (6.4m long) with 1.5mmD WLSF glued into a groove arranged in modules of 64
- The 64 WLSFs on each end will be coupled to a Hamamatsu M64 multi-anode PMT, which has 64 light receiving pixels
- To be able to readout and compare data from each of these 64 pixels, the gain across the pixels must be equalized
- WLSFs are threaded through each piece of scintillator and each trigger counter. These are then mapped into different holes in a fiber holder. The fiber holder has a face with 64 holes, and each hole corresponds to one pixel of the PMT. This means that the light from each strip, and trigger counter can be measured individually by looking at the light in an individual PMT 10 pixel.



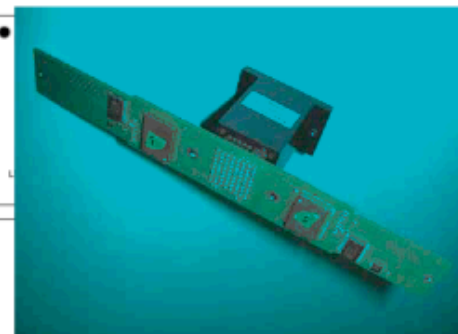
Electronics



- The 64 channels enter a MAROC2 custom integrated circuit, which allows for adjustment of the electronic gain of each of the 64 channels
- The output of the MAROC2 will be fed into an FPGA, which will record the time of hits, buffer the data, provide control signals for the MAROC2, and provide a signal to the central system when data are present and are to be readout
- A parallel to serial converter will be used to transfer data to central receiver boards when the FPGA is polled by the main system



MAROC2 Chip



Electronics: cost

- The cost per electronics board is about \$1000.
- Each PMT is \$1740.
- So for \$2740 you have the readout for 64 channels.
- The PMT price was for a large order of 150.
Smaller orders will be more expensive.

G4Beamline

- “The primary purpose of G4Beamline is to track particles and see where they go (or don’t go).” –Tom Roberts
- I have gotten a simple case to run: proton beam through a box target consisting of air, water, bone, water, air.
- Things to work on:
 - More sophisticated target
 - Add scintillator detector
 - Will try to apply simple cuts
 - Will look at output ntuple and try to understand it

